Energy is the inherent capacity of the universe to make matter exist.

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SES 194

Energy in Everyday Life

Fusion

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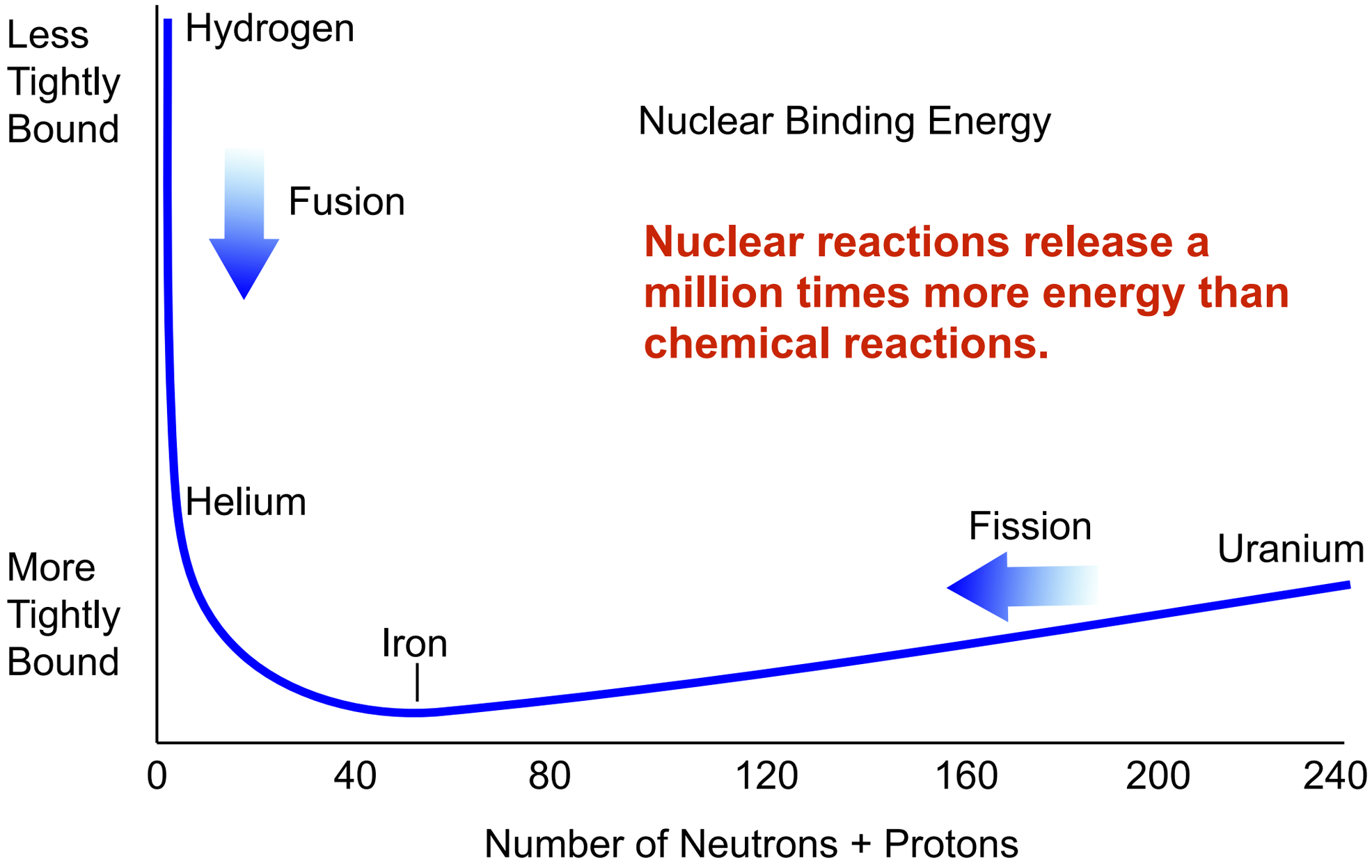
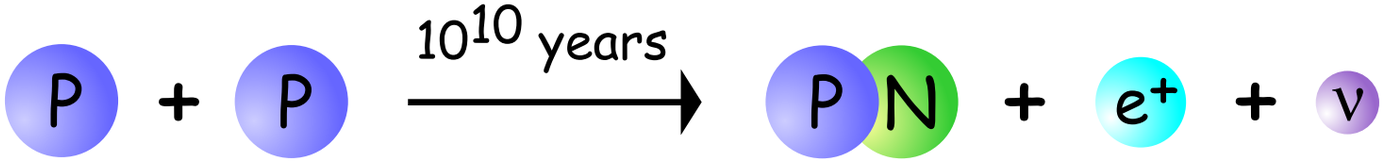
Fusion is combining two or more pieces into a single entity.

For the fusion of light nuclei such as hydrogen, enormous amounts of energy can be extracted to do work.

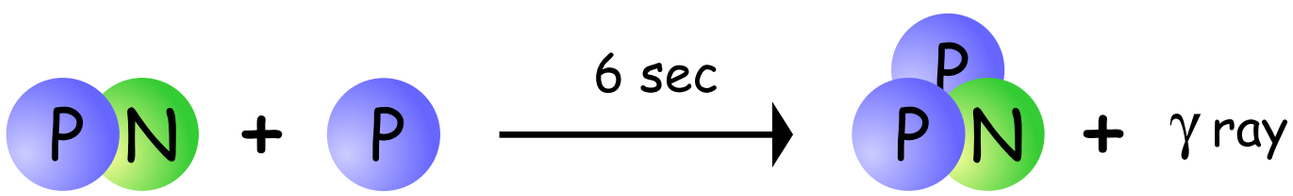


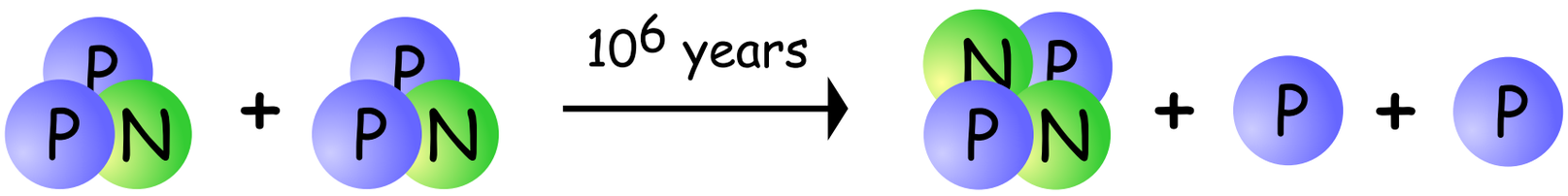
Fusion reactions is what powers the Sun and other stars.

For most of their lives, stars get their energy from "burning" protons, the simplest of all possible reactions.



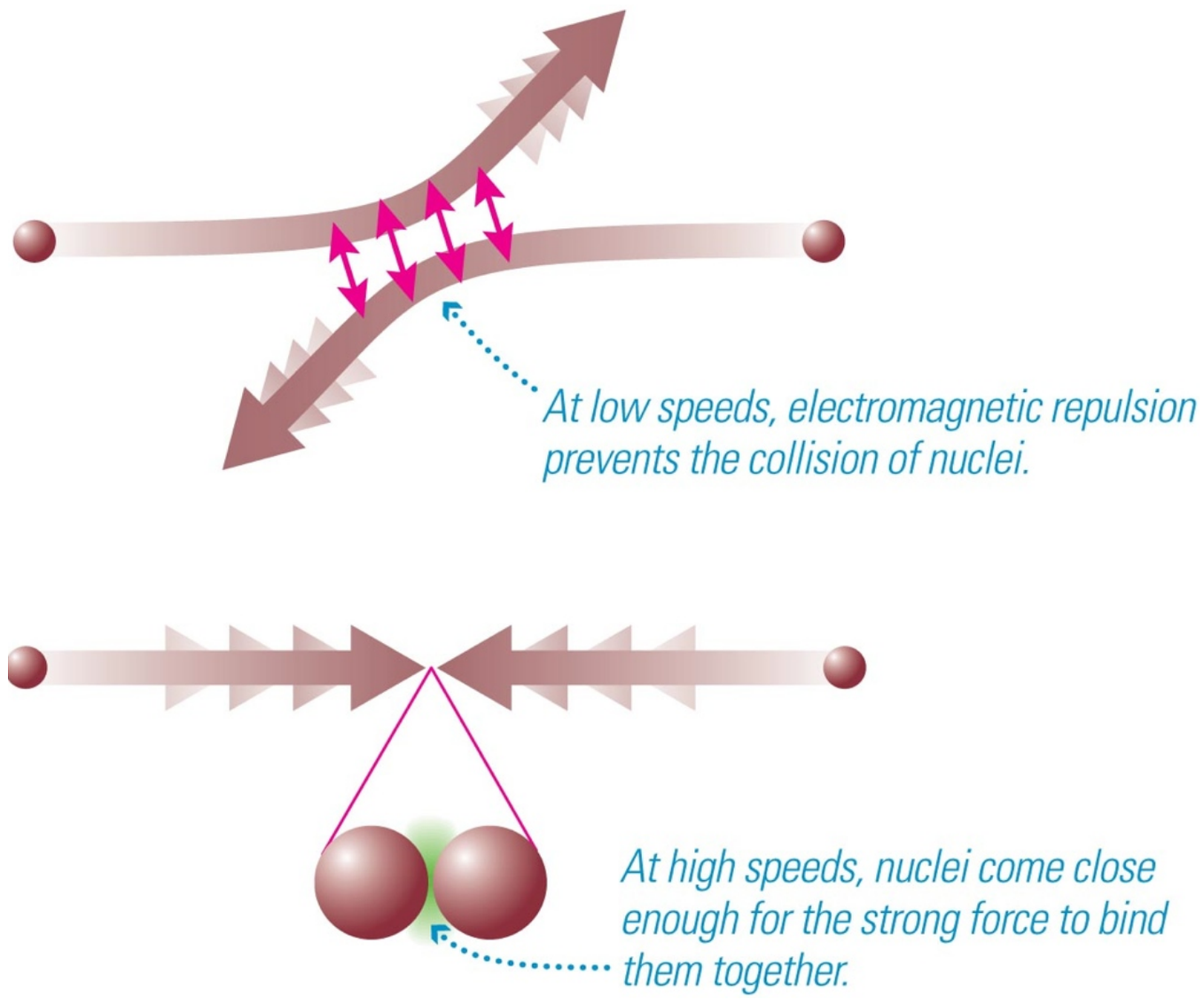
This is the limiting step. The Sun has a long lifetime because this reaction is rare.





4 hydrogen get burned into 1 helium. The mass of the 4 hydrogen is larger than mass of the 1 helium. The "missing" mass is converted to energy, $E= mc^2$.

To get this large fusion energy out out, a large activation energy must be supplied as protons begin to burn at around 15 million K.



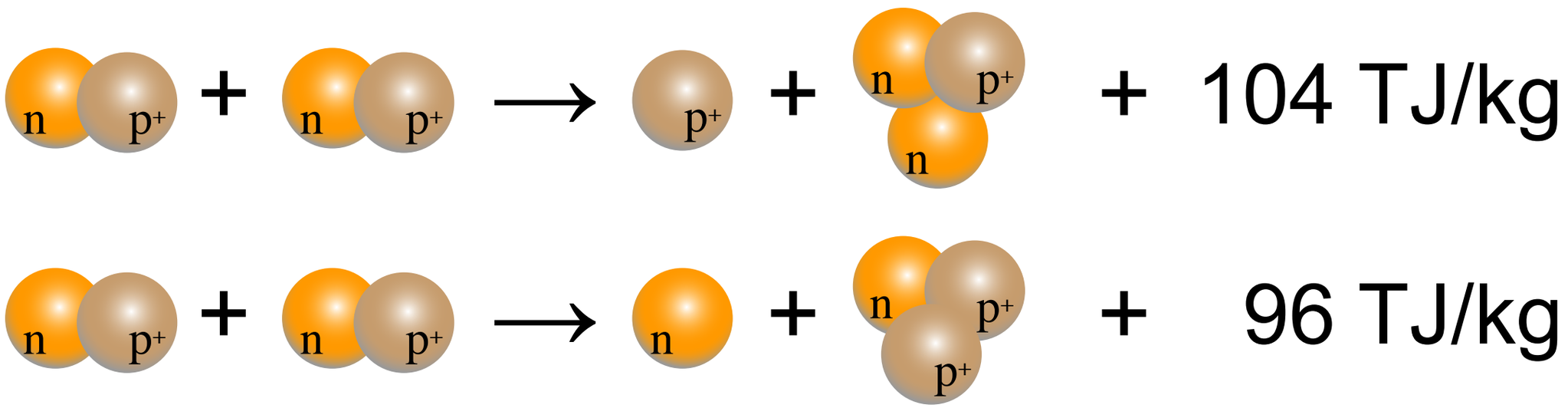
On Earth, the need for a large fusion activation energy adds a considerable complication for fusion power plants.

15 million K at the Sun's center is just enough to keep the protons burning, but the Sun is so huge it seems prodigious.

On Earth, we'll need higher temperatures of ~100 million K to get a worthwhile fusion rate.

Mimicking the Sun's proton + proton reaction is unfeasible since the reaction is so rare. We are better off starting with deuterium, ^{2}H. We lose some energy as we start lower on the binding energy curve, but the fusion rates are larger.

On Earth, these fusion reactions are considered practical enough for potential use in power plants:



One out of every ~7000 hydrogen atoms are deuterium ^{2}H.

Thus, every cubic meter of seawater contains ~34 gr of ^{2}H.

For the ^{2}H + ^{2}H reaction at ~100 TJ/kg, the oceans can supply enough ^{2}H to power the humanity, at 2012 USA energy levels, for ~50 billion years, longer than the age of the universe.

The current cost of extracting ^{2}H is about $\$10^{-6}$ per kWh, so the entire USA could be powered for ~$1000/hour.

A fusion power plant also has significantly less radioactive debris to dispose than a fission power plant.

Fusion appears a cornucopia - unlimited, cheap, clean power.

The catch is that small-scale, sustained, energy producing fusion has not been achieved, despite 50 years of trying.

We know its possible - stars do it and hydrogen bombs are uncontrolled fusion devices. The question is can it be controlled and operate on a scale smaller than a star.